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High resolution SAR applications and instrument design

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ABSTRACT

The Synthetic Aperture Radar (SAR) has viewed, in the last years, a huge increment of interest from many preset and potential users.

The good spatial resolution associated to the all weather capability lead to consider SAR not only a scientific instrument but a tool for verifying and controlling the human daily relationships with the Earth Environment. New missions have been identified for SAR as spatial resolution became lower than three meters : disasters , pollution , ships traffic , volcanic eruptions, earthquake effect are only few of possible objects which can be effectively detected, controlled and monitored by SAR mounted on satellites. This paper deals with high resolution radar design constraints and dimensioning .

INTRODUCTION

The recent years have been characterized by a increasing of interest on remote sensing by SARs both for civil and not civil applications. The technology development can now assure new features to SAR sensors and spacecraft missions can be better tailored to the specific user requirement.

The two key parameters for new missions are: revisit time and resolution.

The first parameter deals with the mission definition, coverage, orbits selection and the number of satellites which can be allocated in orbit at the same time. The high resolution permits the analysis of manmade or natural objects with the capability of their detection and in same case their identification. Furthermore high resolution leads to better radiometric resolution for the conventional applications where pixel dimensions requirement are less stringent. A resolution better than three meters is generally requested for these Surveillance Missions but the target is to reach the one meter resolution within next decade. Civil applications could be identified in the controlling and monitoring of environment areas and phenomena like:

- Pollution
- Fires
- Volcanic activity
- Ships traffic control
- Land traffic control
- Environmental disasters
- Crisis monitoring
- Urbanization control
- coast erosion

The high resolution is generally attractive in countries like Europe where we find high population density and limited land extension so the number of objects to be discriminated is very large.

Alenia Spazio has been involved , in the last few years, in a number of studies for high resolution SAR sensor and their potential applications. In this note only few considerations will be provided identifying the most significative aspects of high resolution SAR design.

REQUIREMENT OVERVIEW

The main requirement of an high resolution SAR sensor are here below identified:

parameter	unit	high resolution mode	survey mode
range resolution	meters	1 to 3	5 to 100
azimuth resolution	meters	1 to 3	5 to 100
swath extension	Kmeters	5 to 10	50 to 400
sensitivity	dB	-20	-20
number of looks	-	1	1 to 16
azimuth ambiguities ratio	dB	-22	-22
range ambiguity ratio	dB	-22	-22
radiometric accuracy	dB	< 2	< 1
access area	degree	30 to 60 +	20 to 60 +
polarization	-	HH or VV	HH or VV/ HH and VV
altitude	Kmeters	550 to 800	550 to 800

The high resolution is obtained in the range direction by wide bandwidth (BW) chirp transmission. The figure 1. shows the bandwidth needs as function of angle of incidence for a defined resolution. The minimum BW for one meter resolution is 300 MHz if 30 Deg incidence angle is requested. Now if we look to the International Regulation about frequency allocation for RADAR applications (S: 200 MHz, C: 100 MHz, X: 300 MHz ,Ku: 600 MHz), then we discover that only X and Ku bands can be used for the scope.

The azimuth resolution can be obtained by a conventional stripmap mode with two meters antenna length or the most promising spotlight mode which consists of increasing the conventional synthetic aperture by tracking with the antenna beam the ground swath. This implies azimuth steering capability in the antenna. Figure 2. gives the frequency dependence of resolution in case only the quadratic term of the SAR echo is compensated into the processing. The present compression algorithms should be improved for high resolution processing looking in particular to the depth of focus and to the combination of the discrete synthetic sub apertures produced by the antenna steering.

The Swath dimensions for high resolution SAR is limited mainly by the data rate but should be pointed out that in case of spotlight mode the antenna dimensions are heavily affected because the azimuth beam width should fit with swath dimension in the along track direction. Then the antenna height is dictated by ambiguities (minimum antenna area) and link budget considerations. The result of dimensioning appears in an antenna with 15 / 20 square meters area, narrow in the along track direction. Therefore in some cases, when it is requested to combine high resolution with a survey-medium resolution / medium swath mode, it becomes difficult to find swath coverage solution without using the complex Scansar technique . Alternatively antenna beam forming by TR modules weighting or switching-off a certain number of TR modules, so reducing the antenna height , are techniques to be attempted. The drawbacks of spotlight mode are the need of an active antenna with azimuth steering and the gaps on ground between an images and the next one (fig 4 .). The gap for an X band sensor is in the order of one/ two times ,depending on satellite altitude and incidence angle, the Swath dimension in the azimuth direction. The access area (fig 3.) is important in determining the revisit time of the sensor and the incidence angle at which a "spotswath" could be viewed. The access area lower limit comes from resolution/ BW requirement while the upper limit from link budget/ antenna dimension constraints.

The multipolarization doesn't seem essential to surveillance mission SAR adding complexity to the system without dramatically improving detection capability. The spacecraft altitude is defined from mission requirement and impacts specifically high resolution in antenna dimension and data rate. The data rate of an instrument like we are outlining in this notes has a data rate in the order of one Gigabit/sec. This high amount of data can be transmitted to ground directly or by a Data Relay Satellites which are under study for the next future.

CONCLUSIONS

ALS has studied the high resolution implementation on SAR sensor. The result shows that the design is feasible in X band where resolution can be achieved and technology is available. The selected solution is based on spotlight mode: active antenna is requested with azimuth steering capability (1/2 Deg) for azimuth resolution and elevation steering capability (20/ 30 Deg) for imaging within the access area.

Range resolution

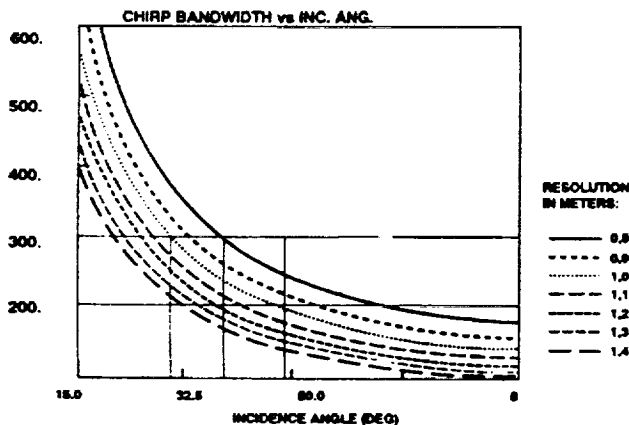


fig.1.

Max achievable resolution (azimuth) Frequency dependence

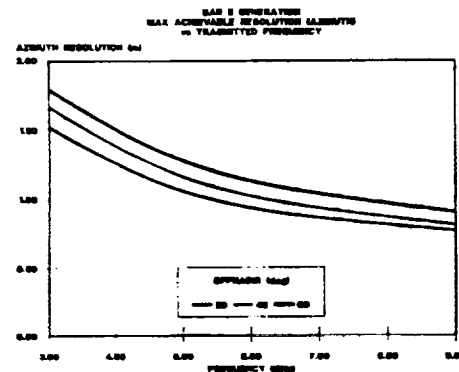


fig.2.

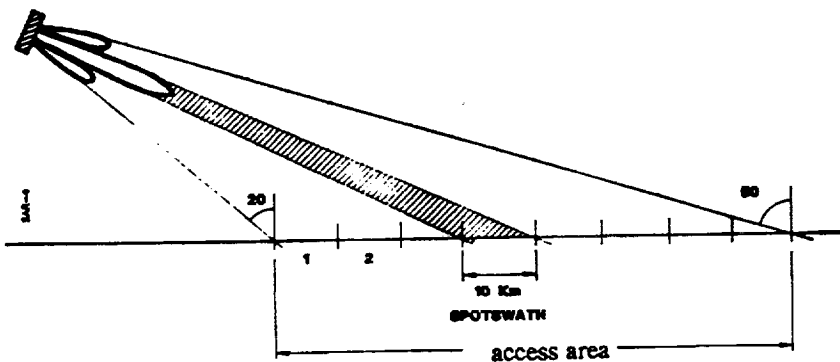


fig.3.

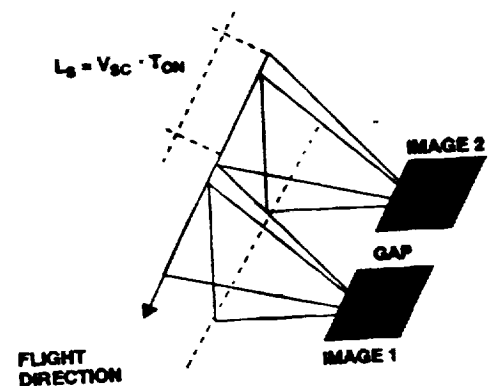


fig.4.

